Appendix B

Emission Calculations

Individual and combined heat input rate limits for the Gas turbines, HRSGs, Emergency Generator, and Diesel Engine are given below in **Table B-1**. These are the basis of permit conditions limiting heat input rates.

Table B-1 Maximum Allowable Heat Input Rates

Source	MM Btu/hour-source	MM Btu/day-source	MM Btu/year-source
S-1 and S-3 Gas Turbines, each	1,979.4	47,506[a]	17,339,544[b]
S-1 CTG and S-2 HRSG, each S-3 CTG and S-4 HRSG, each	2,179.4[c]	52,306[d]	17,227,954[e]
S-6 Emergency Generator	6.44	19.3[f]	1,288[g]
S-7 Diesel Engine	2.11	5.3[h]	63[i]

[a]based upon specified maximum rated heat input of 1,979.4 MM Btu/hr and 24 hour per day operation

[b]based upon 8,760 hours of operation at full load (1,979.4 MM Btu/hr)

[c]maximum combined firing rate for gas turbine and HRSG duct burners

[d]based upon maximum duct burner firing of 24 hours per day; calculated as:
(24 hr/day)(2,179.4 MM Btu/hr) = 52,306 MM Btu/day

[e]based upon maximum annual duct burner firing of 1,500 hr/year-HRSG, 6,844 hr/yr gas turbine full load, and 156 hr/yr of cold startup and 260 hr/yr of hot startup at one-half full load fuel rate (990 MM Btu/hr); calculated as:

(1,500 hr/yr)(2,179.4 MM Btu/hr) + (6,844 hr/yr)(1,979.4 MM Btu/hr)
+ (416 hr/yr)(990 MM Btu/day) = 17,227,954 MM Btu/year/unit

[f]based upon maximum emergency generator firing of 3 hours per day (non-emergency); calculated as:
(3 hr/day)(6.44 MM Btu/hr) = 19.3 MM Btu/day

[g]based upon 200 hours of non-emergency operation at full load; calculated as:
(200 hr/yr)(6.44 MM Btu/hr) = 1,288 MM Btu/yr

[h]based upon maximum engine operation of 2.5 hours per day (non-emergency); calculated as:
(2.5 hr/day)(2.11 MM Btu/hr) = 5.3 MM Btu/day

[i]based upon 30 hours of non-emergency operation at full load; calculated as:
(30 hr/yr)(2.11 MM Btu/hr) = 63 MM Btu/yr

Table B-2 Maximum Annual Facility Emissions from Permitted Sources (ton/yr)

Source	NO_2	CO	POC	PM_{10}	SO_2
S-1 Gas Turbine and S-2 HRSG[a]	77.0	291.9	13.8	41.7	12.1
S-3 Gas Turbine and S-4 HRSG[a]	77.0	291.9	13.8	41.7	12.1
S-5 Cooling Tower				3.0	
S-5 Emergency Generator	0.2	0.3	0.2		
S-6 Diesel Engine		0.1			
Total Permitted Emissions	**134.6[b]**	**584.2**	**27.8**	**86.4**	**24.2**

[a]includes gas turbine start-up and shutdown emissions
[b]the maximum annual NO_x emissions is not derived from summing NO_x emissions from all sources. It is specified by the applicant and is said to reflect real operating scenarios. Permit conditions will limit NO_x emissions based on 134.6 ton/yr.

B-1.0 Gas Turbine Start-Up and Shutdown Emission Rate Calculations

The maximum nitrogen oxide, carbon monoxide, and precursor organic compound emission rates from a gas turbine occur during start-up and shutdown periods. The PM_{10}, sulfur dioxide, ammonia, and toxic compound emissions are a function of fuel use rate only and do not exceed typical full load emission rates during start-up.

Table B-3 Gas Turbine Start-Up Emission Rates (lb/hr)

Pollutant	Cold Start-Up[a]	Hot Start-Up[b]
NO_x (as NO_2)	80	80
CO	838	902
POC	16	16
PM_{10}	9	9
SO_x (as SO_2)	1.37	1.37

[a]cold start not to exceed 180 min.
[b]hot start not to exceed 60 min.

Hot Start-Up Emission Rate Calculations

- Maximum duration: 60 min.

NITROGEN OXIDES (as NO_2)

Maximum NO_x emission rate: 80 lb/hr

Total NO_2 = 80 lb/hot start

CARBON MONOXIDE

Maximum CO emission rate: 902 lb/hr

Total CO = 902 lb/hot start

PRECURSOR ORGANIC COMPOUNDS

Maximum POC emission rate: 16 lb/hr

Total POC = 16 lb/hot start

PARTICULATE MATTER (as PM_{10})

- PM_{10} emissions are not increased during start-up
- PM_{10} emission factor based upon full load operation (emission rate of 9 lb/hr)

Total PM_{10} = **9 lb PM_{10}/ hot start**

SULFUR DIOXIDE

- SO_2 emissions are not increased during start-up

Total SO_2 = **1.37 lb SO_2/hot start**

Cold Start-Up Emission Rate Calculations

- Maximum duration: 180 min.

NITROGEN OXIDES (as NO_2)

Maximum NO_x emission rate: 80 lb/hr

Total NO_2 = 240 lb/cold start

CARBON MONOXIDE

Maximum CO emission rate: 838 lb/hr

Total CO = 2,514 lb/cold start

PRECURSOR ORGANIC COMPOUNDS

Maximum POC emission rate: 16 lb/hr

Total POC = 48 lb/cold start

PARTICULATE MATTER (as PM_{10})

- PM_{10} emissions are not increased during start-up
- PM_{10} emission rate during start-up equals maximum baseload emission rate of 9 lb/hr

Total PM_{10} = **27 lb PM_{10}/cold start**

SULFUR DIOXIDE

- SO_2 emissions are not increased during start-up

Total SO_2 = **4.11 lb SO_2/cold start**

B-2.0 Worst-Case Operating Scenarios and Regulated Air Pollutant Emissions for Gas Turbines, HRSGs, Natural Gas Engine, Fire Pump Engine, and Cooling Tower.

The Gas Turbine/HRSG emission rates shown in **Table B-4** are the basis of permit condition limits and emission offset requirements and were also used as inputs for the ambient air quality impact analysis. To provide maximum operational flexibility, no limitations will be imposed on the type or quantity of turbine start-ups. Instead, the facility must comply with rolling consecutive twelve month mass emission limits at all times. The mass emission limits are based upon the emission estimates calculated for the following power plant operating envelope:

- 6,844 hours of baseload (100% load) operation per year for each gas turbine
- 1,500 hours of duct burner firing per HRSG per year with steam injection power augmentation at gas turbine combustors
- 260 hours of hot start-ups total per year each
- 156 hours of cold start-ups total per year each

Table B-4: Maximum Annual Regulated Air Pollutant Emissions for Gas Turbines HRSGs[a], Natural Gas Engine, Fire Pump Engine, and Cooling Tower

Source (Operating Mode)	NO_2 (lb/yr)	CO (lb/yr)	POC (lb/yr)	PM_{10} (lb/yr)	SO_2 (lb/yr)
S-1 & S-3 Gas Turbines (520 hr/yr of hot start-ups)	41,600	469,040	8,320	4,680	712
S-1 & S-3 Gas Turbines (312 hr/yr of cold start-ups)	24,960	261,456	4,992	2,808	427
S-1 & S-3 Gas Turbines (13,688 total hours[a] @ 100% load)	194,506[b]	352,192[c]	33,809[c]	123,192[c]	18,753[c]
S-1 & S-3 Gas Turbines and S-2 & S-4 HRSGs (3000 total hours[a] w/duct burner firing and steam injection power augmentation)	46,950[d]	84,990[e]	8,160[e]	36,000[e]	4,530[e]
S-5 Cooling Tower				6,132[f]	
S-6 Emergency Generator[g] (200 hours per year)	355	603	284	1	1
S-7 Diesel Engine[h] (30 hours per year)	117	71	14	4	3
Total Emissions (lb/yr)	308,488	1,168,352	55,579	172,817	24,426
(ton/yr)	**154.2**	**584.2**	**27.8**	**86.4**	**12.2**

[a]total combined firing hours for both turbines

[b]based upon the heat input rate of 1,979.4 MM Btu/hr for each gas turbine and annual average NO_2 concentration of 2.0 ppmvd

[c]based upon the heat input rate of 1,979.4 MM Btu/hr for each gas turbine

[d]based upon the maximum combined heat input rate of 2,179.4 MM Btu/hr for each CTG/HRSG power train and annual average NO_2 concentration of 2.0 ppmvd

[e]based upon the maximum combined heat input rate of 2,179.4 MM Btu/hr for each CTG/HRSG power train

[f]based upon an emission rate of 0.7 lb/hr operated 8760 hr/yr.

Circulation Rate: 135,000 gpm
Drift Rate: 0.0005%

Water Mass Rate: 67,554,000 pph
(135,000 gal/min)(60 min/hr)(8.34 lb/gal)

TDS = 0.7 x 10^6/(67,554,000 x 0.000005) = 2072 ppm (maximum)

[g]emission rates from vendor guarantee

[h]emission rates from vendor guarantee

B-3.0 Worst-Case Toxic Air Contaminant (TAC) Emissions

The maximum toxic air contaminant emissions resulting from the combustion of natural gas at the S-1 & S-3 Gas Turbines, S-2 & S-4 HRSGs, S-5 Cooling Tower, S-6 Emergency Generator, and S-7 Diesel Engine are summarized in **Table B-5, B-6, B-7 and B-8**. These emission rates were used as input data for the health risk assessment modeling. The derivation of the emission factors is detailed in Appendix A.

Table B-5 Gas Turbines and HRSGs – Toxic Emissions

Pollutant	CATEF Emission Factor[a] (lb/MM scf)	Factor Used (lb/MM scf)	Emissions Per Turbine[b] (lb/yr)
Acetaldehyde	6.86E-02	6.86E-02	1.162E+03
Acrolein[c]	2.37E-02	6.43E-03	1.089E+02
Ammonia[d]	6.63E+00	6.63E+00	1.123E+05
Benzene	1.36E-02	1.36E-02	2.303E+02
Butadiene-1,3	1.27E-04	1.27E-04	2.150E+00
Ethylbenzene	1.79E-02	1.79E-02	3.031E+02
Formaldehyde	1.10E-01	1.10E-01	1.863E+03
Hexane	2.59E-01	2.59E-01	4.385E+03
Naphthalene	1.66E-03	1.66E-03	2.811E+01
PAHs[c]	1.06E-04	6.60E-04	1.118E+01
Propylene	7.71E-01	7.71E-01	1.305E+04
Propylene Oxide	4.78E-02	4.78E-02	8.094E+02
Toluene	7.10E-02	7.10E-02	1.202E+03
Xylene	2.61E-02	2.61E-02	4.419E+02

[a] CARB's CATEF Version 1.2 Database emission factors, mean values

[b] Based on maximum heat input rate of 17,440,000 MMBtu per year, or fuel rate of 16,932 MMscf/yr

[c] Acrolein and PAHs rates are from Calpine source test results.

[d] Ammonia emission rate is estimated based on 5 ppm ammonia slip (15% O2)

Natural gas heat value used to convert units = 1030 Btu/scf

Table B-6 Cooling Tower (S5) – Toxic Emissions

Contaminant	Emission Factor (ppm)	Annual Total (ton/yr)
Ammonia[b]	4	5.924E-3
Arsenic	0	0
Cadmium	0	0
Chromium III	0	0
Copper	0	0
Lead	0	0
Mercury	0	0
Nickel	0	0
Silver	0	0
Zinc	0	0
PAHs	0	0

[a] The cooling tower uses recycled water from the City of Hayward's water pollution control facility. An advanced water treatment, utilizing reverse osmosis and micro filtration removes dissolved solids (TDS) and HAPs from the plant feedwater.

[b] based upon a drift rate of 338 lb/hr

Table B-7 Natural Gas Emergency Generator (S6) – Toxic Emissions

Pollutant	CATEF Emission Factor[a] (lb/MM scf)	Factor Used (lb/MM scf)	Annual Total (ton/yr)
Acetaldehyde	5.29E-01	5.29E-01	6.615E-01
Acrolein[c]	5.90E-02	5.90E-02	7.378E-02
Benzene	2.18E-01	2.18E-01	2.726E-01
Formaldehyde	2.87E+01	2.87E+01	3.589E+01
Naphthalene	1.22E-01	1.22E-01	1.526E-01
Benzo(a) anthracene	7.78E-05	7.78E-05	
Benzo(a) pyrene	3.55E-05	3.55E-05	
Benzo(b) fluoranthene	3.27E-04	3.27E-04	
Benzo(g,h,I) perylene	1.03E-04	1.03E-04	
Benzo(k) fluoranthene	5.30E-04	5.30E-04	
Dibenz (a,h) anthracene	1.09E-05	1.09E-05	
Indeno (1,2,3-cd) pyrene	1.20E-04	1.20E-04	
PAHs[c] (total)	1.20E-03	1.20E-03	1.501E-03
Propylene	1.87E+01	1.87E+01	2.338E+01
Toluene	4.12E-01	4.12E-01	5.152E-01
Xylene	4.94E-02	4.94E-02	6.177E-02

[a] CARB's CATEF II Database emission factors, mean values

[b] Based on 200 hours per year of non-emergency operation with fuel heat content of 1030 Btu/scf:
(6.44 MMBtu/hr)(200 hr/yr)/1030 Btu/scf = 1.25 MM scf/yr

Table B-8 Diesel Fired Engine (S7) – Toxic Emissions

Pollutant	CATEF Emission Factor[a] (lb/M gal)	Factor Used (lb/M gal)	Annual Total (ton/yr)
Acetaldehyde	3.47E-03	3.47E-03	1.568E-03
Acrolein[c]	1.07E-03	1.07E-03	4.836E-04
Benzene	1.01E-01	1.01E-01	4.565E-02
Formaldehyde	1.32E-02	1.32E-02	5.966E-03
Naphthalene	1.63E-02	1.63E-02	7.368E-03
Benzo(a) anthracene	5.03E-05	5.03E-05	
Benzo(a) pyrene	1.81E-05	1.81E-05	
Benzo(b) fluoranthene	7.96E-05	7.96E-05	
Benzo(g,h,I) perylene	3.89E-05	3.89E-05	
Benzo(k) fluoranthene	1.56E-05	1.56E-05	
Dibenz (a,h) anthracene	2.43E-05	2.43E-05	
Indeno (1,2,3-cd) pyrene	2.89E-05	2.89E-05	
PAHs[c] (total)	2.56E-04	2.56E-04	1.157E-04
Propylene	3.85E-01	3.85E-01	1.740E-01
Toluene	3.74E-02	3.74E-02	1.690E-02
Xylene	2.68E-02	2.68E-02	1.211E-02

[a] CARB's CATEF II Database emission factors, mean values

[b] Based on 30 hours per year of non-emergency operation with fuel heat content of 140,000 Btu/gal:
(2.11 MMBtu/hr)(30 hr/yr)/140,000 Btu/gal = 0.452 Mgal/yr

Table B-9 Total Toxic Emissions

Pollutant	Gas Turbines and HRSGs (lb/yr)	Cooling Tower (lb/yr)	Emergency Generator (lb/yr)	Diesel Engine (lb/yr)	**Total (lb/yr)**
Acetaldehyde	2.32E+03		6.615E-01	1.568E-03	**2.325E+03**
Acrolein[c]	2.18E+02		7.378E-02	4.836E-04	**2.179E+02**
Ammonia[d]	2.25E+05	5.924E-03			**2.246E+05**
Benzene	4.61E+02		2.726E-01	4.565E-02	**4.609E+02**
Butadiene-1,3	4.30E+00				**4.300E+00**
Ethylbenzene	6.06E+02				**6.062E+02**
Formaldehyde	3.73E+03		3.589E+01	5.966E-03	**3.762E+03**
Hexane	8.77E+03				**8.770E+03**
Naphthalene	5.62E+01		1.526E-01	7.368E-03	**5.638E+01**
PAHs[c]	2.24E+01		1.501E-03	1.157E-04	**2.236E+01**
Propylene	2.61E+04		2.338E+01	1.740E-01	**2.612E+04**
Propylene Oxide	1.62E+03				**1.619E+03**
Toluene	2.40E+03		5.152E-01	1.690E-02	**2.405E+03**
Xylene	8.84E+02		6.177E-02	1.211E-02	**8.839E+02**

B-4.0 Maximum Facility Emissions

The maximum annual facility regulated air pollutant emissions for the proposed gas turbines and HRSGs have been shown in **Table B-4**. The total permitted emission rates shown are the basis of permit condition limits and emission offset requirements, if applicable.

Table B-10
Maximum Hourly and Daily Regulated
Air Pollutant Emission Rates for Baseload Operation per Power Train
(Excluding Gas Turbine Start-up Emissions)

	NO_2[b]	CO	POC	PM_{10}	SO_2
S-1 and S-3 Gas Turbines[a]					
lb/hr-source	17.8	25.7	2.47	9	1.37
lb/day-source	426	618	59	216	33
S-1 & S-2 and S-3 & S-4 Gas Turbine/HRSG Power Train[c]					
lb/hr-power train	19.5	28.3	2.72	12	1.51
lb/day-power train	469	680	65	288	36

[a]based upon maximum heat input rate of 1979.4 MM Btu/hr for each gas turbine

[b]based upon stack concentration of 2.5 ppmvd NO_x @ 15% O_2

[c]Based upon a maximum combined heat input rate for each gas turbine/HRSG power train of 2,179.4 MM Btu/hr and maximum 24 hours per day duct burner firing

The maximum daily regulated air pollutant emissions per source including gas turbine start-up emissions are shown in **Table B-11**.

Table B-11
Maximum Daily Regulated Air Pollutant Emissions per
Power Train (lb/day)

Source (operating mode)	NO_2	CO	POC	PM_{10}	SO_2
Gas Turbine (Cold Start-up)	240	2,514	48	27	8
Gas Turbine (Full load w/o Duct Burner Firing)	284	412	40	144	22
Gas Turbine & HRSG (Full load w/Duct Burner Firing and steam injection power augmentation)	78	113	11	48	6
Gas Turbine (Hot Start-up)	80	902	16	9	3
Total	**682**	**3,941**	**115**	**228**	**39**

[a]based upon one 60 min. hot start-up, one 180 min. cold start-up, 4 hours of full load operation with duct burner firing @ 2,179.4 MMBtu/hr with steam injection power augmentation, and

16 hours of full load operation without duct burner firing at 1979.4 MM Btu/hr over a 24 hour period. These are the basis of permit condition daily mass emission limits.

Table B-12
Air Pollutant Emission Rates for the Commissioning Period[a] (lb/day)
For Both Units Operating

Source (operating mode)	NO_2	CO	POC	PM_{10}	SO_2
Gas Turbine (Cold Start-up)[b]	480	5,412	96	54	16
Gas Turbine[c] (Full load w/o Duct Burner Firing)	5,680	8,240	80	288	44
Gas Turbine & HRSG[c] (Full load w/Duct Burner Firing and steam injection power augmentation)	1,560	2,260	22	96	12
Gas Turbine (Hot Start-up)[b]	160	1,804	32	18	5
Total	**7,880**	**17,716**	**230**	**456**	**77**

[a]based upon one cold start (3 hrs), one hot start (1 hr), full load operation with duct burner and steam augmentation (4 hrs), and full load operation w/o duct burners (16 hrs)

[b]Emission rates from Table B-3, multiplied by 2 units

[c]POC, PM_{10}, SO_2 emissions are from table B-11 multiplied by two units. NO_2 and CO emissions are mulitiplied by two units and by 10 to account for non-operational SCR and oxidation catalysts during commissioning.

B-6.0 Modeling Emission Rates

The emission rates shown in **Table B-13** were used to model the air quality impacts of the RCEC to determine compliance with State and Federal annual ambient air quality standards for NO_2, CO, and PM_{10}. A screening impact analysis of two gas turbine/HRSG duct burner systems, a 10-cell cooling tower, a natural gas fired emergency generator, and a diesel fire pump engine emission rates and stack gas characteristics revealed that the worst-case impacts occur under the equipment operating scenarios listed.

Table B-13
Emission rates used in modeling analysis (g/s)

Pollutant Source	Max (1-hour)	Commissioning[a] (1-hour)	Start-up[b] (1-hour)	Maximum (8-hour)	Maximum (24-hour)	Maximum Annual Average
NO_x						
Turbine/DB 1	1.591	48.132	1.591	n/a	n/a	1.927
Turbine/DB 2	1.591	n/a	10.08			1.927
Emergency Generator	n/a	n/a	n/a			0.0051
Fire Pump Engine	0.491	n/a	n/a			0.00168
Each CT Cell	n/a	n/a	n/a			
CO						
Turbine/DB 1	2.356	11.9	2.356	41.07[c]	n/a	n/a
Turbine/DB 2	2.356	n/a	113.65	41.07[c]		
Emergency Generator	0.380	n/a	n/a	0.0370		
Fire Pump Engine	n/a	n/a	n/a	n/a		
Each CT Cell	n/a	n/a	n/a	n/a		
PM_{10}						
Turbine/DB 1	n/a	n/a	n/a	n/a	1.134	1.20
Turbine/DB 2					1.134	1.20
Emergency Generator					n/a	0.0000018
Fire Pump Engine					0.000669	0.000055
Each CT Cell					0.00863	0.00863

[a]Commissioning is the original startup of the turbines and only occurs during the initial operation of the equipment after installation. Both turbines will not be commissioned at the same time.
[b]Start-up is the beginning of any of the subsequent duty cycles to bring one turbine from idle status up to power production.
[c]Maximum 8 hour CO emissions include start-up period emissions.